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Kellie Ann Beall, Editor

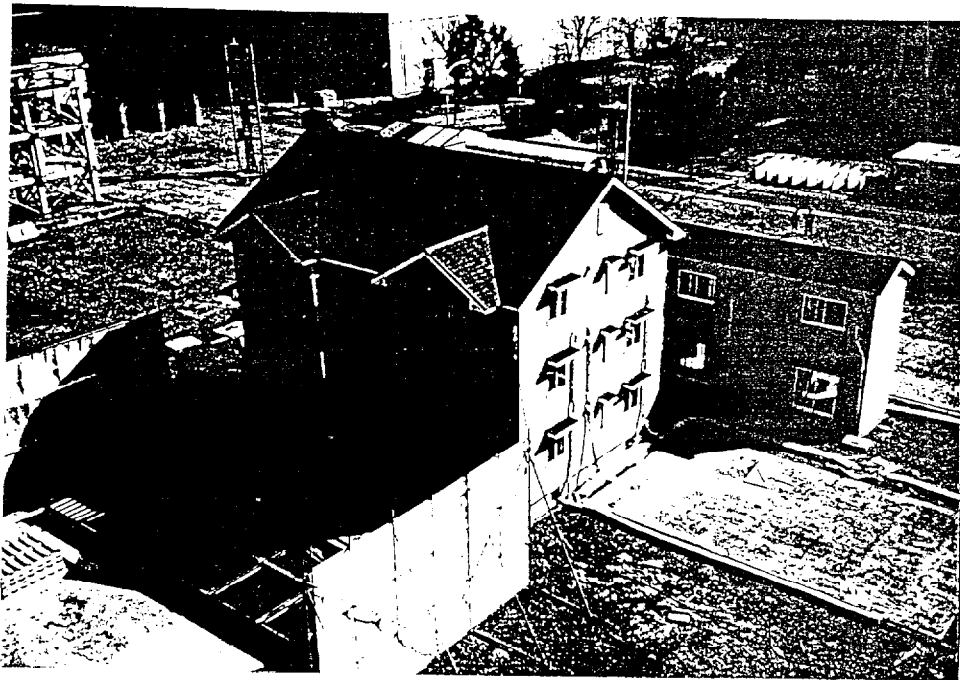


**United States Department of Commerce
Technology Administration
National Institute of Standards and Technology**

FULL-SCALE BURN TEST OF WOODEN THREE-STORY APARTMENT BUILDING

Building Research Institute, Ministry of Construction

March 1996



From left to right: Urban Fire Simulator, Wooden Three-story Apartment Building
and A Test Structure for the Assessment of Fire Spread(Post and Beam Construction)

OBJECTIVE

A full-scale fire experiment has been planned using actual wooden three-story collective housing to obtain technical knowledge necessary for the review of the current building standards regarding wooden structures for possible restructuring. In doing so, the test will examine not only fire safety of a single building but its effects to the neighboring area assuming a city fire.

CONCEPT OF THE BURN TEST

The burn test essentially tries to assess fire safety of wooden three-story collective housing in urban area. As revealed by the recent Hanshin Earthquake, urban fire is still a potential disaster especially in densely inhabited urban area, and it is a main reason for the exclusion of large wooden buildings in urban area in the current building regulation. Although the previous wooden three-story apartment building burn test in 1991 dealt with risk of fire spread from a dwelling unit to other units and to adjacent structures, impact that fire of such building may cause in urban fire scenario is not yet clarified in engineering manner. In order to assess fire safety of wooden three-story apartment building in urban fire scenario, the test will simulate an urban fire with liquid-fuel pools and porous burners assuming a city area with dense unprotected or only weakly-protected wooden structures, and expose a wooden three-story apartment building. As repression of fire spread velocity is the important fire safety performance of buildings needed specifically in urban area, the test tries to evaluate risk of fire spread to buildings behind the wooden three-story apartment building through various measurements and observations. For this purpose, two wooden two-story buildings have been built at the minimum distance allowed by relevant regulations from the wooden three-story apartment building. These buildings have been built according to the Building Standard Law and reflect very common design specifications. Also heat flux, radiation and temperature are measured on the external walls and the windows of the buildings for further analysis and generalization of the test data.

Walls of the buildings used for this test have been damaged artificially to simulate leakage due to earthquake. Although there are different construction methods of wooden buildings such as post and beam construction, 2 x 4 construction and prefabricated construction, the 2 x 4 construction has been adopted for the wooden three-story apartment building. In order to assess fire safety performance of the other construction methods, a series of loaded fire resistance tests are planned on external wall panels of the 2 x 4 construction, the post and beam construction and the prefabricated construction. Fire resistance tests on undamaged external wall panels of these three construction methods were conducted at the occasion of the previous wooden three-story apartment building burn test. At this present project, the specimens will be deflected horizontally at two levels before fire resistance tests to reproduce post-earthquake condition of the wall assemblies.

FACILITY

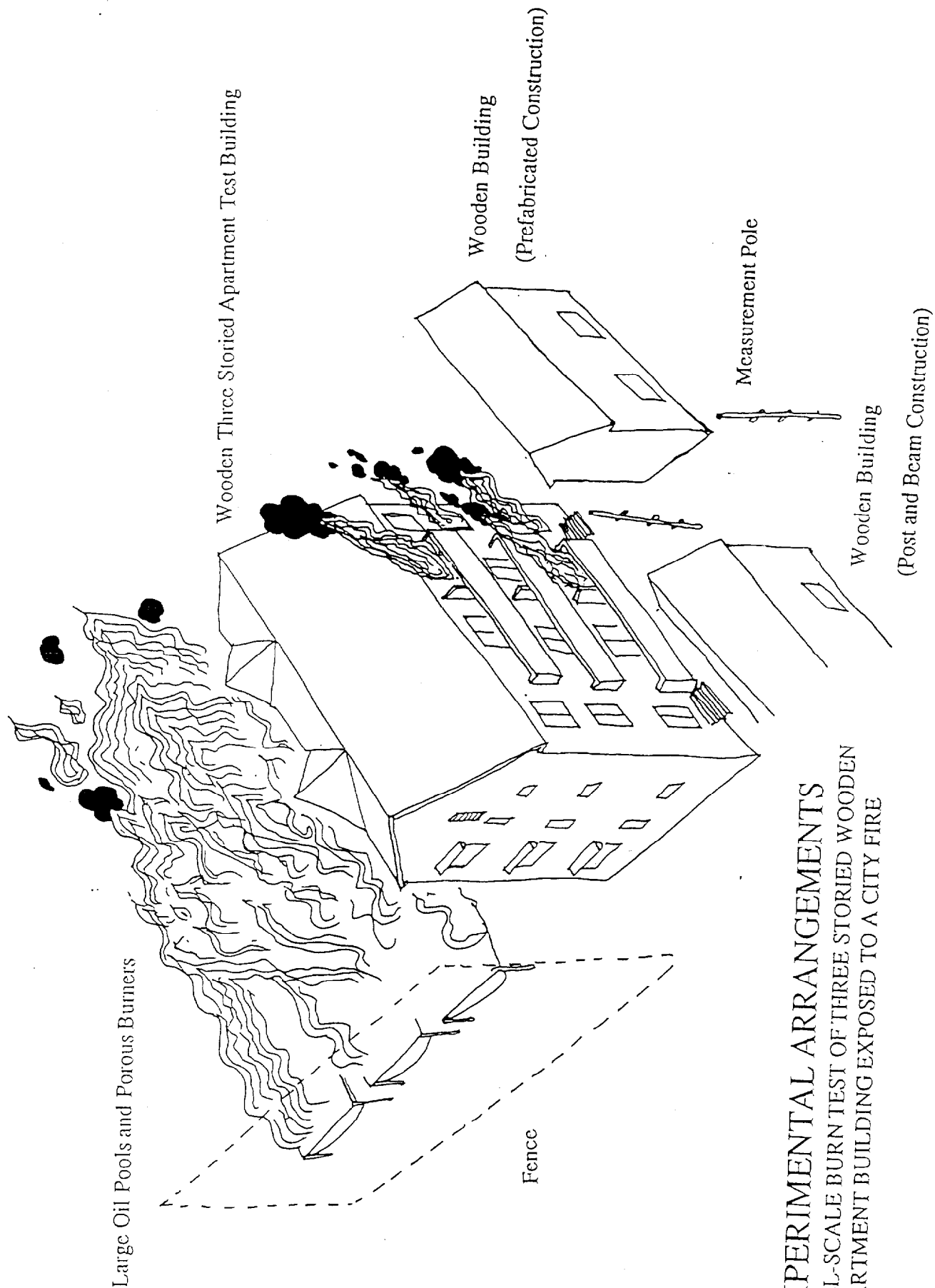
The burn test is carried out using the urban fire simulator, a wooden three-story apartment building test house and two test structures for the assessment of fire spread. These facilities have been built in BRI's Fire Test Field for this particular project.

1) Urban Fire Simulator

A facility to reproduce flames at a city fire in densely inhabited urban area with approximately 2.0 square liquid-fuel pools and porous propane burners. The 12 square pools with n-heptane as the fuel are designed to simulate flaming wooden buildings in urban area, and the 6 propane burners are used to adjust heat release rate and to simulate remaining fires of collapsed buildings.

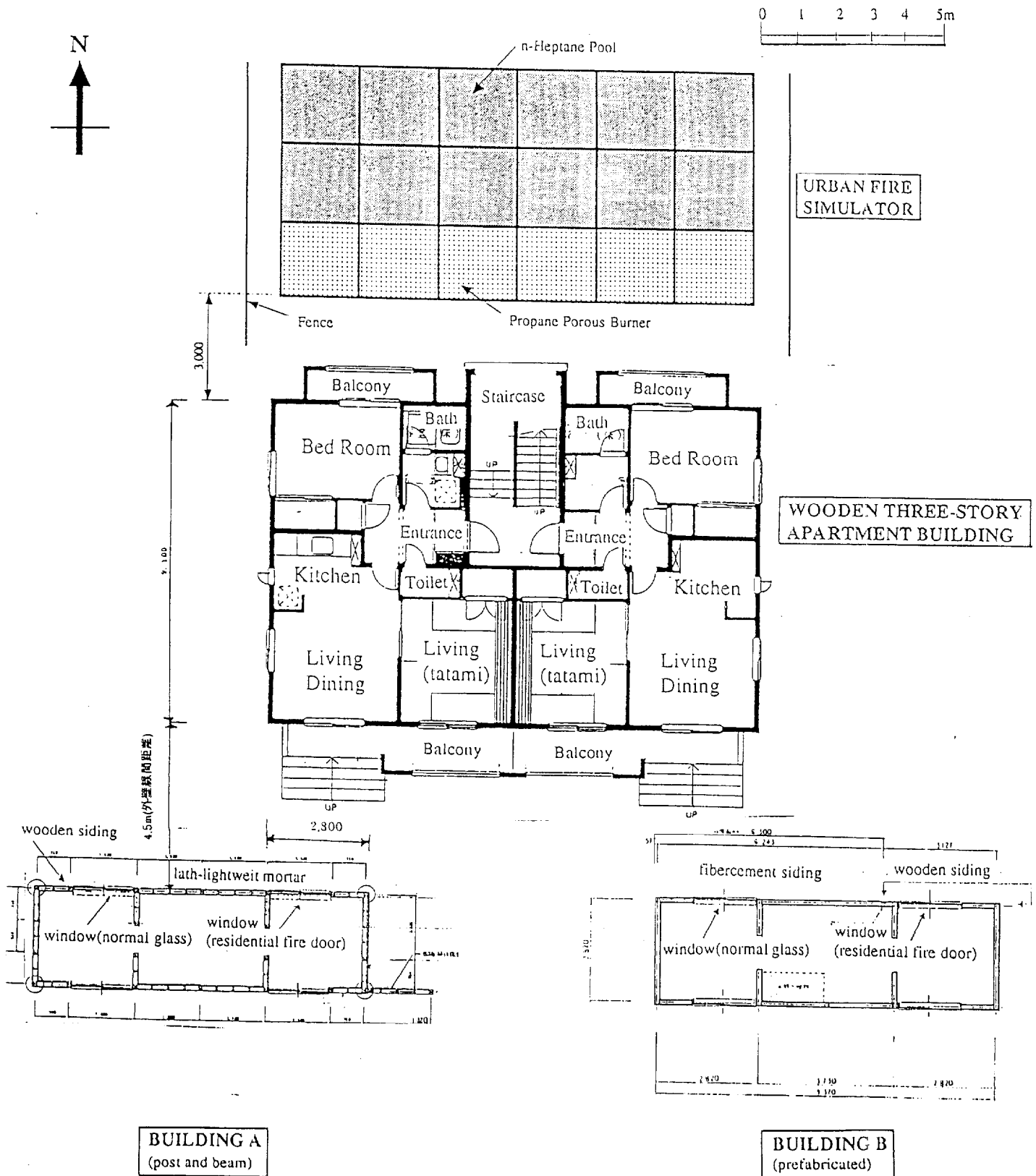
2) Wooden Three-story Apartment Building

A wooden three-story apartment building(2x4 construction, 2 dwelling units per floor, total 6 dwelling units) has been built next to the urban fire simulator. The building's north external wall is 3 m away from the south edge of the urban fire simulator. Each dwelling unit occupies 55.9m², so the total floor area excluding the external staircase and balconies becomes approximately 335m². Fire safety aspects of the building was designed basically to conform the current Japanese Building



EXPERIMENTAL ARRANGEMENTS
FULL-SCALE BURN TEST OF THREE STORIED WOODEN
APARTMENT BUILDING EXPOSED TO A CITY FIRE

FULL-SCALE BURN TEST OF WOODEN THREE-STORY APARTMENT BUILDING FACILITY LAYOUT



Wooden Three-story Apartment Building

General

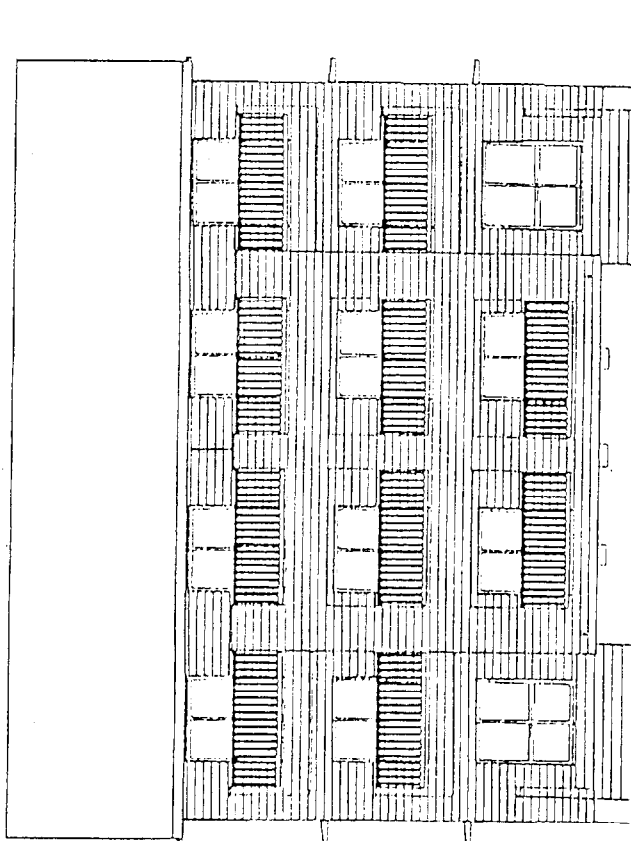
construction	2 x 4 construction
height	11.69 m
total floor area	335.37 m ² (excluding the external staircase and balconies)
floor area of dwelling unit	55.89 m ²

Main specifications

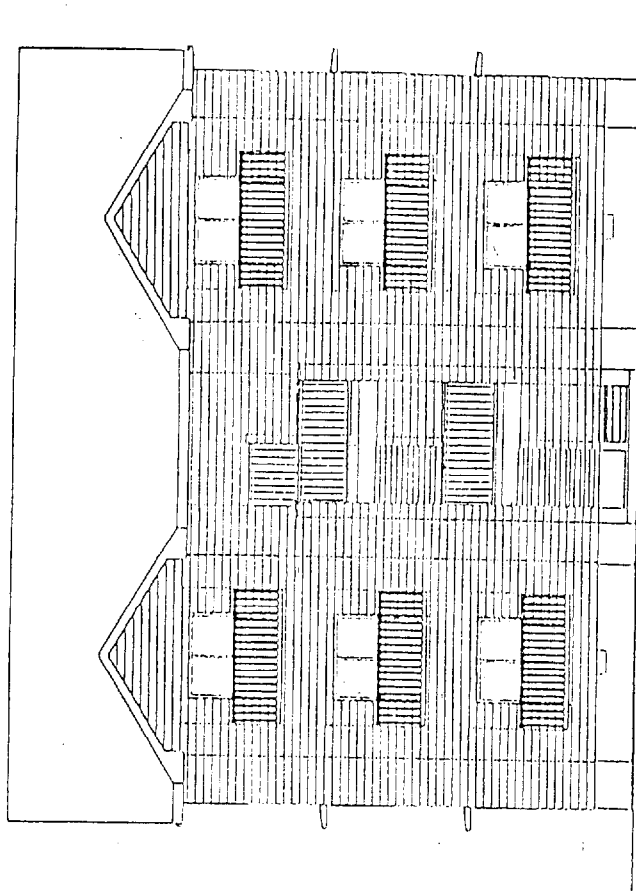
External Surfaces			
roof	residential roofing slate		
eaves	hard tip cement board 12mm		
external wall	fiber cement board siding 15mm		
entrance door	Type-B fire door		
window	residential fire window with wired glass, pilot model(<i>Type-B fire door</i>) (within the possible <i>portion liable to catch fire</i>) normal glass(outside the possible <i>portion liable to catch fire</i>)		
attic ventilator (at eaves)	with fire damper		
Internal Surfaces			
	1st floor	2nd floor	3rd floor
floor	wood 12mm	gypsum board 12.5mm	
internal surface of external walls	gypsum board 12.5 mm + 12.5 mm		
partitions(load bearing walls)	gypsum board 12.5 mm + 12.5 mm		
partitions(other than load bearing walls)	gypsum board 12.5 mm		
ceiling	gypsum board 12.5 mm + 12.5 mm		gypsum board 9.5mm + 9.5mm(west unit)* gypsum board 12.5mm + 12.5mm(east unit)**
interior lining finish	vinyl cloth	none	none
equipments	with building service equipments and lights (west unit) none(east unit)	none	none
fire load	furnitures(30kg/m ²) (west unit) wood crib(30kg/m ²) (east unit)	wood crib(30kg/m ²)	wood crib(30kg/m ²)
staircase(external)	wooden		

* 30 minutes *quasi fire resistance*(according to *wooden three-story collective housing*)

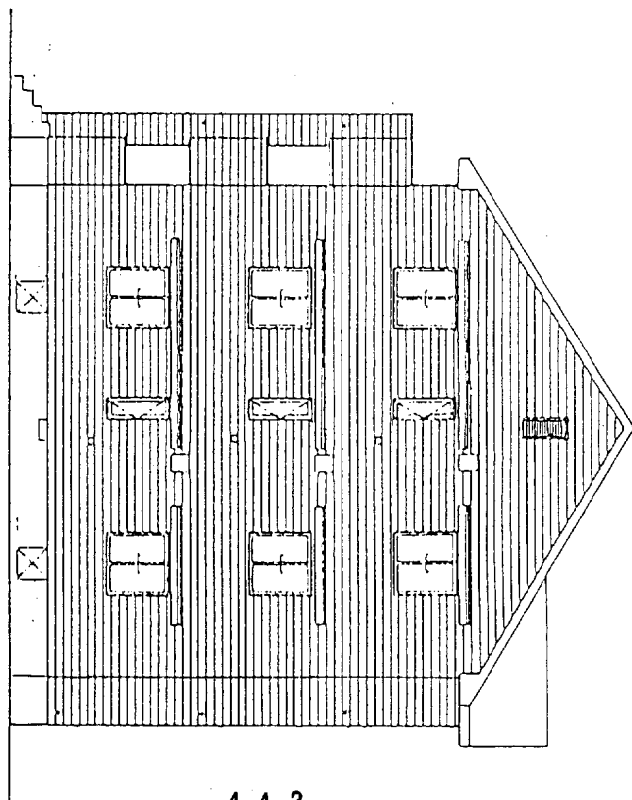
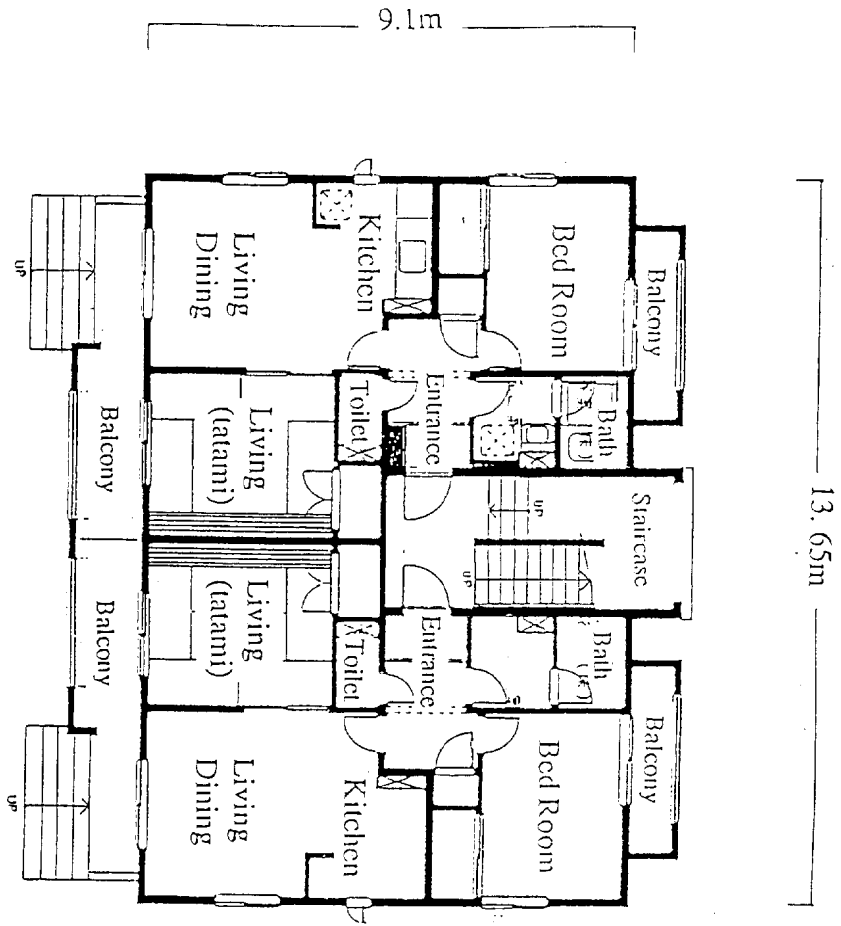
** 45 minutes *quasi fire resistance*(according to *three-story wooden independent house*)



South Elevation



North Elevation



Test Condition of the Wooden Three-story Apartment Building

west		east	
<u>Attic</u>	Attic ventilation opening installed with fire damper	attic ventilation opening installed with fire damper	
<u>3rd Floor</u> Short pent roof, Normal glass	Fire load: 30kg/m ² (wood crib) Windows: north Type-B closed south Type-B closed Partitions with cracks Mattress hang from balcony	Fire load: 30kg/m ² (wood crib) Windows: north Type-B open south Type-B open Partitions without cracks	<u>3rd Floor</u> Long pent roof, Type-B fire door
<u>2nd Floor</u> Short pent roof, Normal glass	Fire load: 30kg/m ² (wood crib) Windows: north Type-B closed south Type-B open Partitions with cracks	Fire load: 30kg/m ² (wood crib) Windows: north Type-B open south Type-B closed Partitions with cracks Mattress hang from balcony	<u>2nd Floor</u> Long pent roof, Type-B fire door
<u>1st Floor</u> Short pent roof, Normal glass	Fire load: 30kg/m ² (furniture) Windows: north Type-B open south Type-B open Partitions with cracks	Fire load: 30kg/m ² (wood crib) Windows: north Type-B closed south Type-B closed Partitions with cracks	<u>1st Floor</u> Long pent roof, Type-B fire door
	Ventilation opening under floor : open	Ventilation opening under floor : with metal mesh	
Two-story building A(post & beam)		Two-story building B(prefabricated)	

Standard Law for *wooden three-story collective housings** which are allowed to build outside the *fire protection and quasi-fire protection districts* with a few exceptions for research purposes. The ceiling of one dwelling unit at the third floor was designed to have 45 minutes *quasi-fire resistance* performance, a requirement for *three-story wooden independent houses*, whereas the another unit on the third floor has 30 minutes *quasi-fire resistant* ceiling according to the requirement for the *wooden three-story collective housings*.

* Terms in italics in this section represent translation of legal terms appearing in the Building Standard Law.

The external and internal walls of five units out of the six dwelling units have been damaged artificially to reproduce post-earthquake condition of the load bearing walls. The leakage data at the previous wooden three-story apartment building burn test in 1991 has been referred to at the present test. No artificial damage was given to the load bearing walls of the east dwelling on the third floor in order to evaluate influence of the damage on leakage and fire resistance through comparison with results from other dwelling units.

Windows with wired glass conforming the *Type-B fire doors* are applied to the windows located virtually within the *portion liable to catch fire*. Each window at the north and south side of the building has curtains. One window at the north side on each floor is left open and the other on each floor is closed. Layout of the opening condition of the windows on the south side has been arranged to produce all possible combinations of opening conditions of the dwelling units. Fire load of the living room, tatami room, bed room and entrance hall of each dwelling unit is 30kg/m^2 , approximately 50% higher than the average reported by investigations. This fire load is represented by real furnitures in the west dwelling unit on the first floor and by timber cribs in other units.

3) Test Structures for the Assessment of Fire Spread

Two wooden two-story buildings(post-and-beam construction and prefabricated construction) of almost identical plan have been built 4.5m south of the external wall line of the wooden three-story apartment building in order to assess the risk of fire spreading to adjacent buildings from wooden three-story apartment in city fire scenario. Each building has approximately 50m^2 total building floor area, and its fire safety aspects were determined according to the Building Standard Law. Most common materials are selected for the external wall lining of the two buildings. The distance to the wooden three-story apartment building is the minimum according to the regulation on the *wooden three-story collective housings*(at least 4 m between the external wall and property line) and the Civil Law restriction(at least 0.5 m from property line). The external walls and the windows within the *portion liable to catch fire* are of fire preventive construction and *Type-B fire doors*(wired glass) respectively.

MEASUREMENTS

1) Temperature

K-type thermocouples are installed in each room of the dwellings, within major load bearing separation walls, and external-wall surfaces.

2) Heat Flux

Schmidt-Boelter heat flux gages are installed to monitor surface heat flux at the north side walls of the wooden three-story apartment building and the north side of the adjacent two wooden buildings. A heat flux gage is arranged at roughly the center of each north side window on each floor and each south side window on the second and third floor. A pole with heat flux gages and

Test Structures for the Assessment of Fire Spread

<u>General</u>	Building A(west)	Building B(east)
construction	post and beam construction	prefabricated construction
height	7.825m	6.812m
total floor area	49.68m ²	52.84m ²
<u>Main specifications</u>		
<u>External Surfaces</u>		
roof	residential roofing slate	residential roofing slate
eaves	lath-lightweight mortar 17mm (within the <i>portion liable to catch fire</i>)	fiber cement board 12mm
	wood 15mm (outside the <i>portion liable to catch fire</i>)	wood 15mm
external wall	lath-lightweight mortar 17mm (within the <i>portion liable to catch fire</i>)	fiber cement board siding 12mm
	wood siding 15mm (outside the <i>portion liable to catch fire</i>)	wood siding 15mm
window	residential fire window with wired glass, pilot model(<i>Type-B fire door</i>) (within the <i>portion liable to catch fire</i>)	
	normal glass(outside the <i>portion liable to catch fire</i>)	
<u>Internal Surfaces</u>		
floor	structural plywood 12mm	structural plywood 12mm
internal surface of external wall	gypsum board 12.5mm	gypsum board 12.5mm
ceiling	gypsum board 12.5mm	gypsum board 12.5mm
fire load	none	none



Urban Fire Simulator(Preliminary Test)

thermocouples is built between the urban fire simulator and the wooden three-story apartment building. Two similar poles are built on the south side of the wooden three-story apartment building at different distances from the external wall.

3) Gas Analysis

Air in the bed room of each dwelling unit is sampled continuously and analyzed.

4) Smoke Density

Optical smoke density is measured in the living room and the bed room of each dwelling unit.

5) Static Pressure

Static pressure is measured inside a south side opening of each dwelling unit.

6) Infrared Image

Infrared image is recorded from outside the buildings at three different directions.

7) Visual Observation and Video Camera

Several teams watch and record the building and its environment from different angles. Video cameras make visual records of the buildings and fire from at least three different directions. A video camera is installed in the bed room of each dwelling unit to make observation of fire penetration to the room from the urban fire simulator.

TEST SCHEDULE

The burn test will be initiated with the ignition to the urban fire simulator planned at 9:30. In order to make it possible to observe post-fire stability of the wooden three-story apartment buildings, fire suppression of the test buildings will be started at 16:30 unless any risk of fire spread to outside the restricted area or other danger is anticipated.

1) Opening

Introduction of the burn test project and other informations are presented by the BRI Director General and the Director of the Fire, Environment and Design Department. Invited guests are kindly requested to be around the control desk and guest seat by 9:00.

2) Tour in the Restricted Area

Prior to the ignition to the urban fire simulator, invited guests and press crews are invited to a tour to see the building conditions and the instrumentation. The tour members will walk with a guide in the restricted area through the path between the wooden three-story apartment building and the prefabricated test structure. For safety reasons, the tour cannot approach the urban fire simulator.

3) Ignition to the Urban Fire Simulator

Ignition to the urban fire simulator is scheduled at 9: 30. Ignition will be made with torches.

4) Possible Ignition to Dwelling Units

If fire spread from the urban fire simulator to any dwelling unit does not occur, the wooden three-story apartment building will be ignited in the west dwelling unit on the first floor. Even if any dwelling units survive the heating from the urban fire simulator or fires of other dwelling units, all surviving dwelling units will finally be ignited artificially in order to evaluate post-fire structural stability of the wooden three-story apartment building.

5) Briefing in Japanese

It is planned to make brief report in the Japanese language twice at 12:00 and at 17:00 at the Lecture Room of the BRI's International Institute of Seismology and Earthquake Engineering on the first floor of the BRI Main Building.

6) Briefing in English

It is planned to make brief report in English at 17:30 at the Lecture Room of the BRI's International Institute of Seismology and Earthquake Engineering on the first floor of the BRI Main Building.

SAFETY PRECAUTIONS

The burn test is one of the largest scale fire tests in Japan. Generation of a flame large enough and considerable smoke is anticipated from the result of the preliminary test. Also the test deals with large amount of liquid fuel. **BRI requires everyone except for the test team not to enter the restricted area. Smoking in the test site not only in the restricted area is prohibited.** BRI also requests everyone at the test site to follow advice and directions from the headquarter and from the safety crew especially at emergency.

FOR YOUR CONVENIENCE

? Information

For general questions in English or French, please look for Dr.A.Marchal, a guest scientist at the BRI Fire Safety Division. Dr.I.Nakaya is also available for English speakers.

Rest Rooms

Rest rooms for gentlemen and ladies are available on the first floor of the Full Scale Fire Test Laboratory and in the Main Building.

Lunch and Beverage

BRI cafeteria, first floor of the Main Building, is open to public. There are few restaurant around the BRI campus. There are numbers of restaurants in the Central Tsukuba area. Lunch for invited guests is prepared at the reception rooms for invited guests on the second floor of the Main Building. Beverage is available at the entrance lobby of the Main Building.

Smoking

Smoking is not allowed in the test site for safety reasons. The entrance lobby lounge is available for smoking.

First Aid

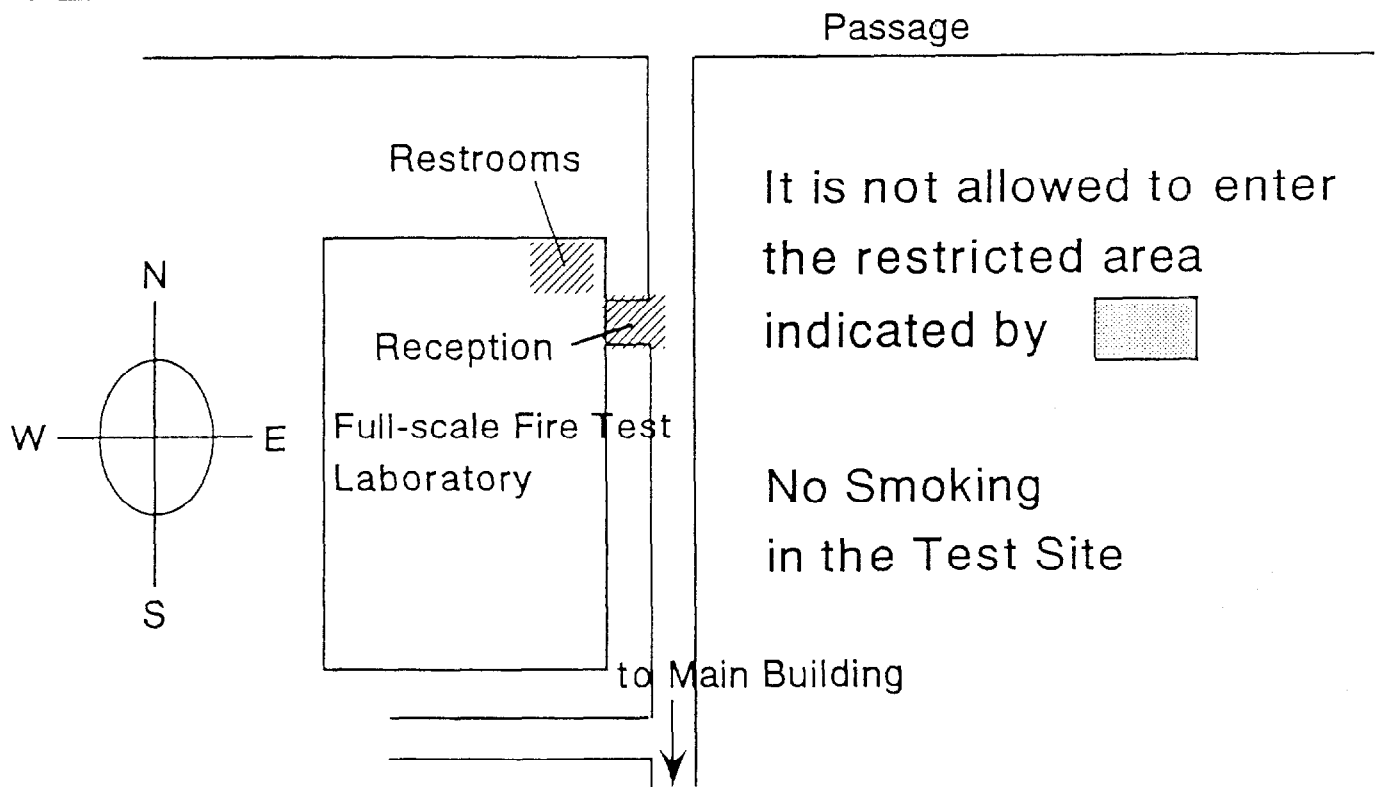
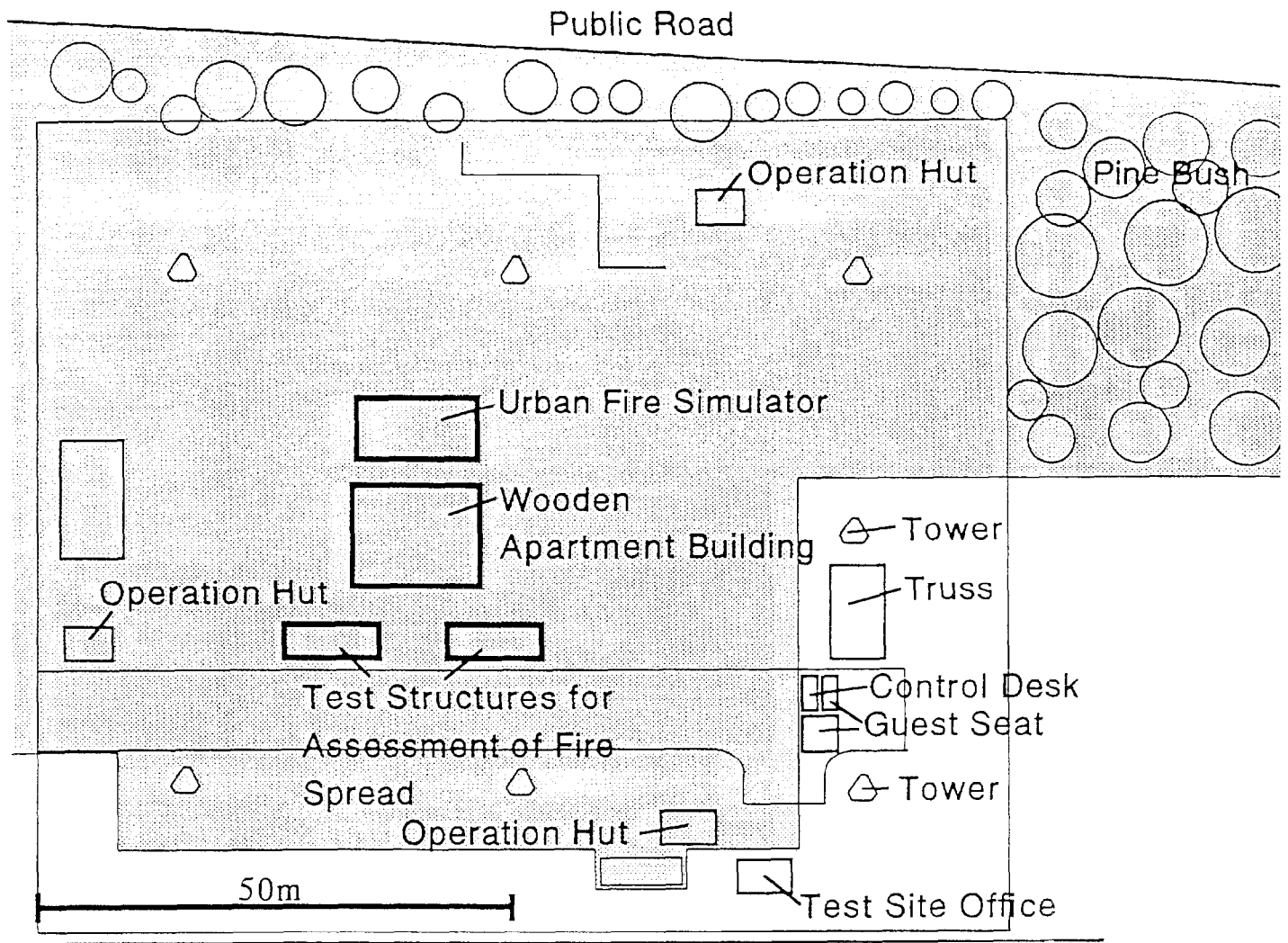
In case of any injury or sudden illness at the test site, please try to contact anyone with an arm band or visit the test site office almost at the south end of the Fire Test Field.

Reception Rooms for Invited Guests

Two meeting rooms on the second floor of the BRI Main Building are reserved for rest and meal of the guests.

Transportation

Free bus to Tsukuba Center Bus Terminal is available near the gate of BRI frequently from 11:00.



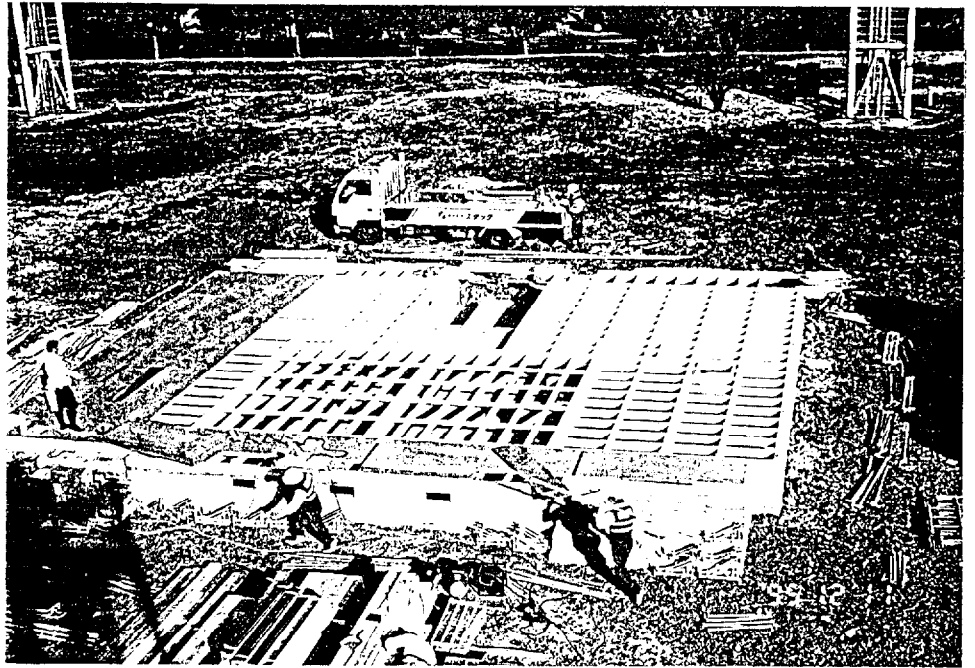
TEST SITE MAP

木造3階建共同住宅実大火災実験棟 工事写真

Construction Works in the Wooden Three-story Apartment Building

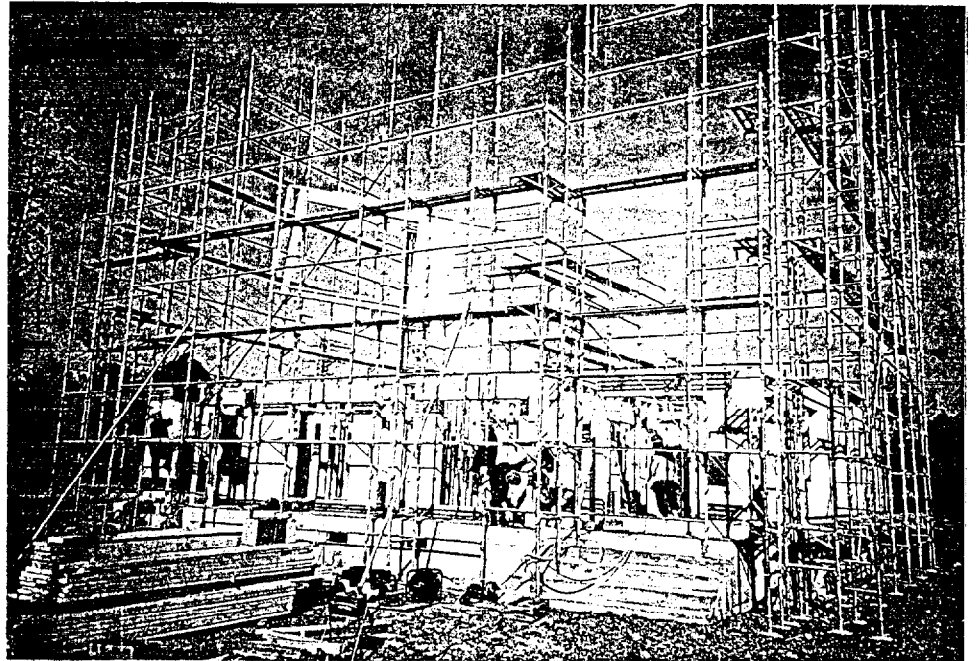
基礎工事終了
1階床組工事中

in process of the first floor
framing work after
completion of the foundation
work



1階壁建起し中

in process of raising the
external walls of the first
floor



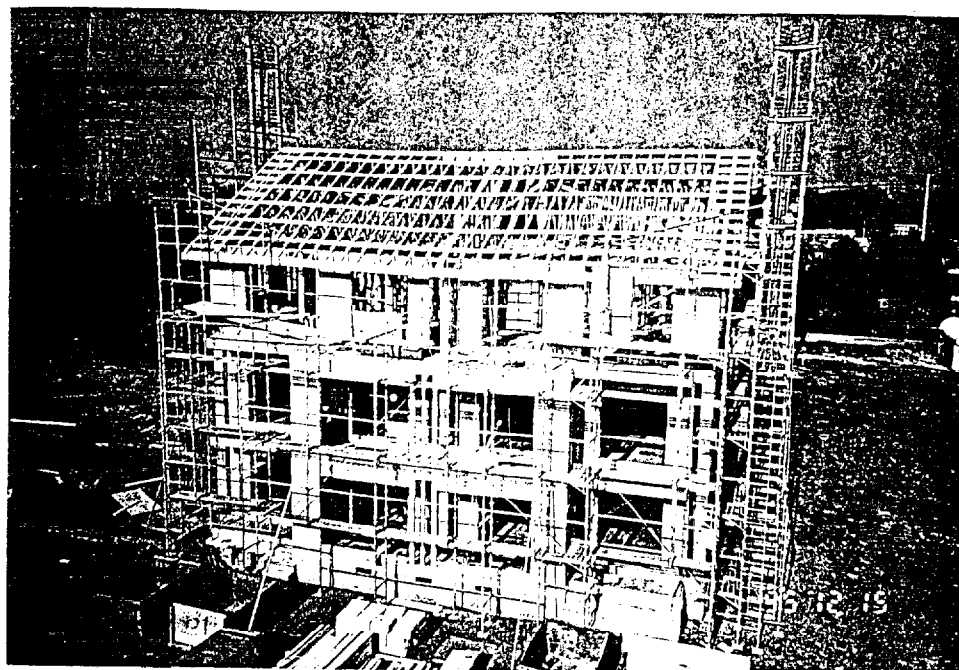
3階壁建起し中

in process of raising the
external walls of the third
floor



小屋組工事中

in process of the roof truss
work



外部仕上工事中

in process of the exterior
finishes



室内石膏ボード張り

interior walls: gypsum board

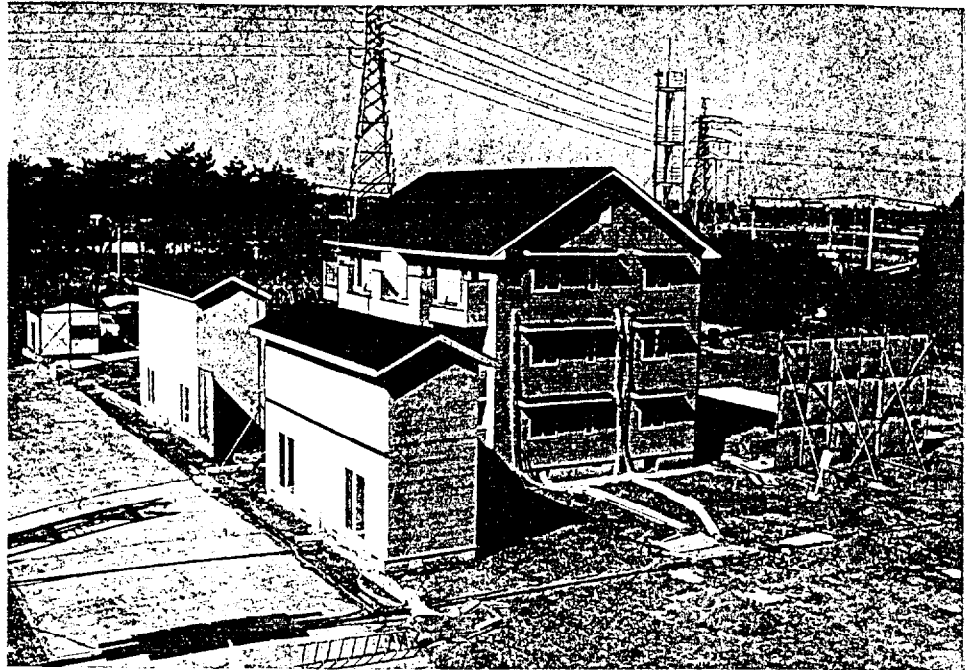


工事完了

left: Post and beam
construction building

right: Prefabricated building

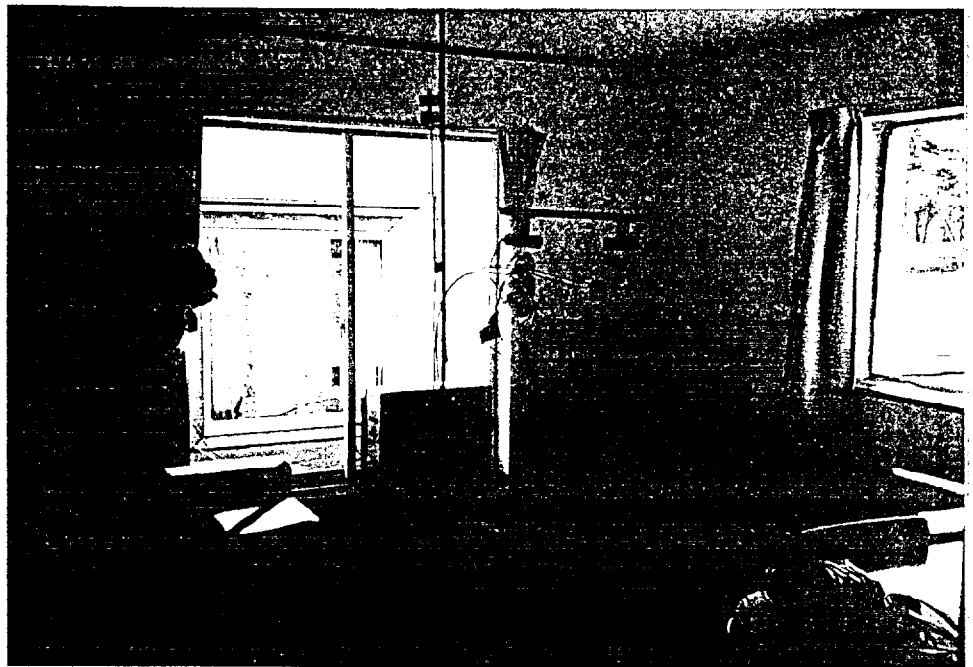
behind the two-story
buildings: wooden three-
story apartment building



居間・食堂

(室内に置かれているポールは
実験用センサー)

Living+Dining Room
(First floor west dwelling)
Poles inside the room are for
measurement sensors



和室

Tatami Room
(First floor west dwelling)

